OPTIMIZATION OF TOOL LIFE USING IN MILLING USING RADIAL BASIS FUNCTION NETWORK

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering *with Manufacturing Engineering.

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Date: 6^{th} DECEMBER 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurently submitted for award of other degree.

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ABSTRACT

This paper discuss of the Optimization of tool life in milling using Radial basis Function Network (RBFN).Response Surface Methodology (RSM) and Neural Network implemented to model the end milling process that are using high speed steel coated HS-Co as the cutting tool and aluminium alloy T6061 as material due to predict the resulting of flank wear. Data is collected from RoboDrill T14i CNC milling machines were run by 15 samples of experiments using DOE approach that generate by Box-Behnkin method due to table design in MINITAB packages. The inputs of the model consist of feed, cutting speed and depth of cut while the output from the model is Flank wear occur on the tool surface. The model is validated through a comparison of the experimental values with their predicted counterparts. The analysis of the flank wear is using IM1700 Inverted Metallograph microscope for examine the minimum size of the flank wear within 0.3mm. The optimization of the tool life is studied to compare the relationship of the parameters involve. Cutting speed is the greater influence to the tool fatigue criterion which is result the performance of the cutting tool. The proved technique opens the door for a new, simple and efficient approach that could be applied to the calibration of other empirical models of machining.

ABSTRAK

Kertas kajian ini membincangkan tentang mengoptimum kekasaran permukaan dalam proses pengilingan manggunakan pendekatan dari Fungsi Asas Rangkaian Berpusat(RBFN). Pendekatan RSM dan NN digunakan dalam menganalisis nilai kerosakan berlaku pada permukaan mata pemotong iaitu besi ketahanan tinggi bersalut untuk memotong campuran aluminium T6061 iaitu bahan kerja bagi eksperimen ini. Data dikumpul dari 15 sample eksperimen yang direka dari kaedah Box-Behnkin di dalam perisian MINITAB mengunakan pendekatan DOE dan mesin pengiling RoboDrill T14i CNC. Data masuk adalah kelajuan memotong, kedalaman memotong dan kadar pergerakan pemotong dan data yang dinilai adalah kadar kehausan pada permukaan alat pemotong. Model ini diaktifkan melalui perbandingan nilai eksperimental dengan ramalan telah dijangka. Analisis kehausan permukaan alat pemotong menggunakan mikroskop terbalik iaitu IM1700 Metallograph untuk menyemak saiz minimum kehausan sisi minimum sebanyak 0.3mm mengikut kadar kajian ditetapkan. Penentuan jangka hayat optima bagi alat pemotong adalah melalui perbandingan di antara hubungan parameter yang terlibat. Hasil kajian menunjukkan kadar kelajuan sesuatu alat pemotong adalah pengaruh yang lebih besar untuk kriteria kerosakan alat. Melalui kajian ini adalah terbukti bahawa teknik dan pendekatan ini telah memberikan satu pendekatan baru, mudah dan efisien yang boleh diterapkan dalam mendapatkan kadar purata untuk jangka hayat sesuatu alat pemotong.

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LIST OF SYMBOLS

mm	-	Millimeter
MPa	-	Megapascal
GPa	-	Gigapascal
%	-	Percent
HB	-	Hardness
kN	-	Kilo Newton
lbf	-	Pound of force
σ	-	Stress
P	-	Load
A_o	-	Cross sectional area
A_f	-	Final crosses sectional area
e	-	Strain
l	-	Instantaneous length
l_o	-	Original length
E	-	Modulus of elasticity
UTS	-	Ultimate tensile strength
Y	-	Yield strength

LIST OF ABBREVIATIONS

AISI	-	American Iron and Steel Institute
ASTM	-	American Society for Testing and Material
CCD	-	Camera Charging Device
CMOS	-	Computer Minimum Operating System
CNC	-	Computer Numerical Control
DOE	-	Design of Experiment
FKM	-	Fakulti Kejuruteraan Mekanikal
HS-Co	-	High Speed Coated
HSS	-	High Speed Steel
ISO	-	International Organization for Standardization
IPM	-	Inches per Minute
MRR	-	Material Removal Rate
NDT	-	Nondestructive Testing
PC	-	Personal Computer
RBFN	-	Radial Basis Function Network
RPM	-	Revolution per Minute
SFM	-	Surface Feet per Minute

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The development of manufacturing have been acknowledge and well developed with the race of time. Manufacturing started with act of commercializing product in market with a high volume of product created. To fulfill the demand of market, conventional machines have been developed throughout the years. One of these so call machines is milling machine, lathe machine and etc. today’s leading manufacturing and companies compete on the basis of time, product cost, quality and quantity. Therefore, machine such as milling machine are beneficial asset as the manufacturing process become easier and effective.

A milling machine is a machine tool used for the complex shaping of material and other solid materials. Its basic form is that of a rotating cutter or endmill which rotates about the spindle axis, and a movable table to which the workpiece is affixed. That is to say the cutting tool generally remains stationary (except for its rotation) while the workpiece moves to accomplish the cutting action.

The milling process is most efficient if the material removal rate is large as possible, while maintaining a high quality level. But, the material removal rate is often limited due to tool wear and failure. These will effect the condition of the tool thus bring lots of problem in productivity, quality, also the economical aspect in machining process. To verify this problem we need to consider the improvement of the tool long term usage which is it life that able to withstand higher fatigue, wear and so on. The tool life improvement is very crucial factor in the manufacturing that needs to have lots of study on to development of new research of the tool itself.

This project are focusing on how to improve the tool life in milling machine through a method using artificial neural network ANN call Radial Basis Function Network. The project is related the practical and theoretical evaluation onto the wear that occur to the tool mainly for flank wear and the crater wear data analysis base on the revision on the subject related to this approach.

1.2 PROBLEM STATEMENT

Milling machine process is base on a rotating cutter that removes material while travelling along various axes with respect to the workpiece that produce waste call chips. Lots of various shapes can be machining by milling machine and it is one of the most common machining processes that capable of economically producing a variety of shape on workpieces.

The process is similar to other machining process such as turning, drilling, and boring, but most of the other latter process is need to utilize multitooth tools and cutter axes with respect to the shape of the product design. Most of it process is on the cutting tools that subjected to high localized stresses at the tip of the tool, high temperature, sliding chip on the rake face, and sliding of the tool on the surface.

The other factor is workpiece material microstructure all these conditions induce tool wear that will adversely affect tool life. To find a good solution to this factor a development of new research has been made to cope with the economically aspect to reduce tool change and it cost, one of it is to improve the tool life using Radial Basis Function Network method. This method is providing the user to gain specific information about the characteristic of the whole structure of a certain suface on the tool material.

1.3 PROJECT OBJECTIVES

The objective of this project is:

a) To understand the behavior of the tool life under the maximum machining process.
b) To optimized the tool life in the milling machine using HSS T6061 tool.
c) Generated knowledge toward the practical lesson and applying the theoretical aspect.

1.4 PROJECT SCOPE

a) Tool life analysis on flank wear using IM 1700 microscope
b) Analyzing the method involved to opyimize the tool life
c) Conduct an experiment for machining using milling machine (CNC or conventional milling)

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The tool life criterion to be used is a basic problem in tool condition monitoring. On-line tool condition monitoring is important to prevent workpieces and tools from damage, and to increase the effective machining time of a machine tool. After Taylor published his famous tool-life equation, numerous techniques and methods of monitoring tool wear have been developed over the years.1 Figure 1 shows the state of tool wear characterized by flank wear, crater wear, nose wear and outer diameter groove. These types of wear, flank wear and crater wear have a dominant influence on the tool life. Depending upon the machining conditions, one of the two types of wear may dominate over the other.

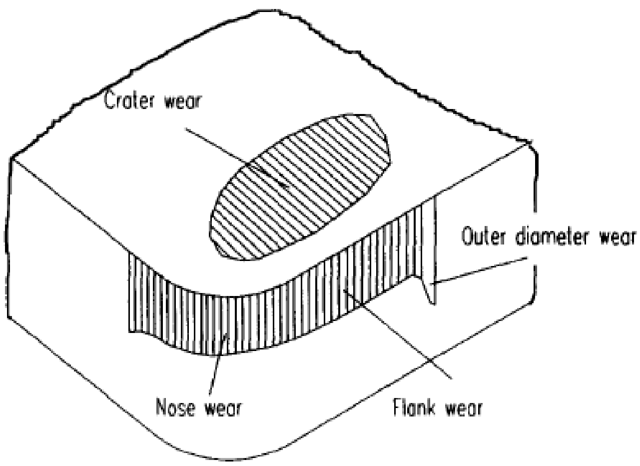

Figure 2.1 Wear characteristic

Generally, the flank wear develops under almost any cutting conditions and its development usually includes three stages. The first stage is a rapid initial wear stage in which the wear develops rapidly to a certain point, within a relatively short time. In the second stage, the wear progresses linearly for a comparatively longer period of time. Most of the useful tool life lies within this stage. The last stage is a rapid, accelerated wearing period. In this stage, the wear rate increases rapidly and it is usually recommended that the tool be replaced before this stage. Flank wear phenomena predominate under low cutting speeds (low cutting temperatures), whereas at high cutting speeds or high feed rates, crater wear is usually more significant. The crater wear is manifested in the form of a dish-shaped hollow on the tool face. The development of crater wear is closely related to the cutting temperature and pressure. The maximum crater depth is generally at a substantial distance from the cutting edge, where the cutting temperature and pressure are high. The crater curvature corresponds to radius of curvature of the chip (the removed workpiece material).

In general, as the crater grows, it will eventually intersect the wear land. 1 Thus, as wear progresses, the general tool geometry can vary considerably. There are many tool-life criteria that depend on various considerations. Basically these criteria can be defined by tool failure (including fracture or chipping, accelerated wear and tool softening), workpiece dimensional tolerance, surface finishing degradation and economic considerations. 2 Under normal machining conditions the flank wear is usually chosen as the basis for tool life criterion. One of the main reasons is that the mechanisms of tool wear have a complex relationship with the properties of the materials of the cutting tool and the workpiece, as well as the variation in cutting conditions.

In a manufacturing system, in order to improve machining efficiency, it is necessary to select the most appropriate from a collection of cutting tools, each with their own history of use. At the time of making this selection, one of the most important tasks is to estimate as accurately as possible the rest of life under given cutting conditions. A multitude of tool information, such as tool wear and cutting force, is proposed to predict tool life. But the applicability of each piece of information in itself is limited to the particular situation for which it was devised. Therefore, a monitoring system processing such information does not always estimate the grade of machinability and/or state of the cutting tool accurately. This is due to the complexity of the cutting process. Tool life is affected by the tool materials, cutting conditions and work materials involved, and depend on the machine tool used. Thus, the prediction of tool life is a kind of ill-structured problem.

2.2 MILLING MACHINE

A milling machine is a machine tool used to machine solid materials. Milling machines are often classed in two basic forms, horizontal and vertical, which refer to the orientation of the main spindle. Both types range in size from small, bench-mounted devices to room-sized machines. Unlike a drill press, which holds the workpiece stationary as the drill moves axially to penetrate the material, milling machines move the workpiece radially against the rotating milling cutter, which cuts on its sides as well as its tip. Workpiece and cutter movement are precisely controlled to less than 0.001 in (0.025 mm).

Figure 2.2 CNC milling machine

Milling machines may be manually operated, mechanically automated, or digitally automated via computer numerical control (CNC). Milling machines can perform a vast number of operations, from simple (e.g., slot and keyway cutting, planning, drilling) to complex (e.g., contouring, die sinking). Cutting fluid is often pumped to the cutting site to cool and lubricate the cut and to wash away the resulting swarf. For CNC milling machine there is a 3 axes which is X, Y, and Z axis for the cutting direction as shown in the figure 2.2.

Refer to figure 2.3 the milling machine that had been use is Fanuc RoboDrill T14i which is has a high performance, compact machine center focused on reliability and speed. At over 1.5G and 2,125 IPM, these compact machines make quick work of any milling, drilling or tapping jobs. Reliability has also been addressed with less than 4 moving parts in its tool changer.

FANUC ROBODRILL T14IA BASIC SPEC	
Machine Type :	VERTICAL
Control :	Fanuc
Number of Axes :	3
X Axis Travel :	500 mm
Y Axis Travel :	380 mm
Z Axis Travel :	300 mm
Tool Stations :	14
Spindles :	1
Motor Power :	0 kw
Spindle Speed :	8000 rpm
Extra Functions :	None

Figure 2.3 The specification of the Fanuc Robodrill T14i

2.2.1 End Milling

In a milling operation, the workpiece is moved around the stationary cutting tool, the tool is moved across the stationary material, or some combination of the two. In any case, material is removed from the workpiece by the rotating tool. The tool is mounted to a chuck or collet and the workpiece is held in place by some sort of vise or other workholding device such as a strap clamp. Vises are good for a horizontal hold while strap clamps are used for vertical. Vertical milling machines, in which the workpiece is moved through two horizontal axes and the cutting tool is moved vertically, are common.

Feed rate and spindle speed for a milling operation can be calculated to optimize for tool wear and surface finish, and depend on several variables, such as tool size, material, and geometry, use of coolant, workpiece material, width and depth of cut, and type of milling operation. Cutting tool manufactures typically supply such information along with the cutting tools.

New cutting geometries as well as coatings are constantly being developed to increase the cutting speed as well as improve surface finish on all types of materials. Programming software is changing the way features are machined into parts. The types of features which used to require a specially ground form tool are now being created using new surfacing and multi-axis technology. However, in some instances it is more cost effective to have a form tool made for large production runs.

2.2.2 Cutting Tool

The two basic cutting tool types used in metalworking are the single-point and multi-point designs. Fundamentally, they are similar. By grouping a number of single point tools in a circular holder, the milling cutter is created. Milling is a process of generating machined surfaces by progressively removing a predetermined amount of material from the workpiece, which is advanced at a relatively slow feedrate to a milling cutter rotating at a comparatively high speed. The characteristic feature of the milling process is that each milling cutter tooth removes its share of the stock in the form of small individual chips.

2.2.3 End-Milling Cutters

End mills can be used on vertical and horizontal milling machines for a variety of facing, slotting and profiling operations. Solid end mills are made from high-speed steel or sintered carbide see figure 2.1. Other types, such as shell end mills and fly cutters, consist of cutting tools that are bolted or otherwise fastened to adapters.

Figure 2.4 End tools for milling machine

Solid end mills — Solid end mills have two, three, four, or more flutes and cutting edges on the end and the periphery. Two flute end mills can be fed directly along their longitudinal axis into solid material because the cutting faces on the end meet. Three and four fluted cutters with one end cutting edge that extends past the center of the cutter can also be fed directly into solid material.

Solid end mills are double or single ended, with straight or tapered shanks. The end mill can be of the stub type, with short cutting flutes, or of the extra long type for reaching into deep cavities. On end mills designed for effective cutting of aluminum, the helix angle is increased for improved shearing action and chip removal, and the flutes may be polished.

2.2.4 High Speed End Mill

End mills (middle row in image) are those tools which have cutting teeth at one end, as well as on the sides. The words end mill is generally used to refer to flat bottomed cutters, but also include rounded cutters (referred to as ball nosed) and radiused cutters (referred to as bull nose, or torus). They are usually made from high speed steel (HSS) or carbide, and have one or more flutes. They are the most common tool used in a vertical mill.

Figure 2.5 4 flute flat end mill HSS

High speed steel (HSS or HS) is a subset of tool steels, usually used in tool bits and cutting tools. It is often used in power saw blades and drill bits. It is superior to the older high carbon steel tools used extensively through the 1940s in that it can withstand higher temperatures without losing its temper (hardness). This property allows HSS to cut faster than high carbon steel, hence the name high speed steel. At room temperature, in their generally recommended heat treatment, HSS grades generally display high hardness (above HRC60) and a high abrasion resistance (generally linked to tungsten content often used in HSS) compared to common carbon and tool steels

High speed steel contains about 7% carbon, 4% chromium plus addition of tungsten, vanadium, molybdenum, and cobalt. These metals maintain their hardness at